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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

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ENTITLED The effects of anxiety on hemispheric processing

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The Effects of Anxiety on Hemispheric Processing

by

Kathryn M. Aebel

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Abstract

The present study investigated the effect of negative mood on the functioning of the right posterior region of the brain. A previous study (Banich et al., 1989) had reported that a depressed mood was associated with a selective increase in reaction time for right but not for left hemisphere trials on a digit-matching task. Since depression is associated with decrease in arousal, the present study examined the effects of anxious mood (which is a negative mood associated with high arousal) on performance of the same digit-matching task. 22 normal subjects were induced into anxious and depressed moods over two separate sessions. It was found that subjects' reaction times during an anxious mood were significantly shorter than reaction time during a neutral mood. However, there was no selective decrease in reaction time for right hemisphere trials. These results suggest that anxiety and depression do not affect functioning of the right posterior region of the brain in the same manner.

Introduction

The asymmetry of the two hemispheres has been the focus of research since Broca's (1865) discovery of speech localization within the left hemisphere. Today it is generally believed that cognitive functions are lateralized in the hemispheres: the left is responsible for verbal, analytical, and sequential functioning, while the right is involved in nonverbal, visuospatial, and holistic processing (Springer & Deutsch, 1989). Just as other cognitive functions are controlled asymmetrically by the hemispheres, the processing of emotion is considered to be lateralized within the brain. Research on brain-damaged and normal populations has supported the notion that the the right hemisphere is specialized for the expression and recognition of emotion.

The role of the right hemisphere in emotion has been observed in a number of different populations including patients with brain lesions, split-brain patients, and non-clinical subjects. People who have sustained damage to the right hemisphere often exhibit deficits in processing emotion. For example, some stroke patients with damage to Broca's area in the right hemisphere lose the ability to convey emotional information through their voices (prosody), even though they are neither aphasic nor do they have mood disturbances (Ross & Mesulam, 1979). In particular, Ross and Rush (1981) observed that patients with right frontal lesions could not easily express emotions through tone of voice, whereas patients with right parietal-occipital lesions had difficulty recognizing emotion conveyed by prosody.

The study of emotional expression in nonclinical subjects also provides important clues as to the role of the right hemisphere in emotion. Since the right hemisphere controls the left side of the face, then facial expression of emotion should be stronger on the left side of the face. Using pictures of a person who was asked to exhibit emotion through facial expression, experimenters have made bisymmetric composites consisting of the left side of the face and its mirror image and right side of the face and its mirror image. When normal subjects were asked to choose which face showed stronger emotion, the left composite faces were chosen more often (Campbell, 1978; Sackeim & Gur, 1978; Barod & Caron, 1980; Rubin & Rubin, 1980). Heller and Levy (1981) showed mirror-image chimeric faces consisting of a smiling half-face and a neutral half-face. Subjects were biased to choose that face as happier when the smile was on the left; this bias was most pronounced when the left half of the face was on the left side of space.

The ability to recognize emotion has been attributed tothe right hemisphere, based on studies of patients with unilateral lesions. Patients with right hemisphere lesions were more deficient than those with left hemisphere lesions in identifying and discriminating emotional tones in spoken speech (Heilman, Scholes, & Watson, 1975; Tucker, Watson, & Heilman, 1977) and in facial expressions (DeKosky, Heilman, Bowers, & Valenstein, 1980). Furthermore, Hoppe and Bogen (1977) report that some split-brain patients are unable to give accurate descriptions of their own emotional states. This would be expected if emotion were being processed in the right hemisphere, because the left hemisphere, which controls speech output, could not talk about it (Springer & Deutsch, 1989).

Dichotic listening techniques provide the means to test how normal subjects perceive the emotional contents of speech. Safer and Levanthal (1977) report that the content of a sentence is used by subjects to judge emotional tone if heard in the right ear, but the speaker's tone of voice is used if heard in the left ear. Since the left hemisphere is analytical and is specialized for verbal processing (Springer & Deutsch, 1989), it would attend to the verbal components of a sentence. However, the right hemisphere would be concerned with cues provided by prosody.

Other evidence for the involvement of the right hemisphere in emotion can be found by measuring brain activity during an emotional state. One would predict that the hemisphere that is involved in the processing of emotion would show greater relative activity during emotional experience. Using EEG recordings of normal subjects, many researchers have reported higher activity over the right hemisphere during emotional states. An increase in right frontal activity (as measured by suppressed alpha waves) was found during an induced depressed mood (Tucker, Stenslie, Roth, & Shearer, 1981), while

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Such patterns are also found in children. Davidson and Fox (1982) recorded the EEG of 10 month old infants watching an actress make happy and sad faces. While the infants watched happy expressions, greater activity was found over the left frontal lobe.

Although much research has supported the notion that the right hemisphere is more specialized for the processing of emotion, there is evidence that the left hemisphere is involved in regulating some aspects of mood. While the right hemisphere seems to control negative mood, the left is important for processing positive mood. A demonstration of how the two hemispheres respond with different types of mood was found when subjects were administered the Wada test. This test consists of injecting a barbituate into one carotid artery and leads to deactivation of the ipsilateral hemisphere, but not the contralateral hemisphere. When the barbituate, sodium Amytal, was injected into the right carotid artery, the subjects became euphoric. However, when the barbituate was injected into the left carotid artery, the subjects had a catastrophic reaction (Terzian & Ceccotto, 1959; Alema, Rosadini, & Rossi, 1961; Perria, Rosadini, & Rossi, 1961; Rossi & Rosadini, 1967). Under these conditions, one would expect the mood controlled by the uninhibited hemisphere to prevail. Since deactivation of the right hemisphere is associated with experiences of euphoria, it appears that the left hemisphere regulates positive mood. Conversely, when the left hemisphere is deactivated, the subject becomes dysphoric, indicating that the right hemisphere regulates negative mood.

Reuter-Lorenz and Davidson (1981) also provide evidence that each hemisphere is involved differently in the recognition of emotion. Subjects were shown two faces, one neutral and the other happy or sad, and were told to pick the face that showed stronger affect. A left visual field advantage was found for sad faces, but right visual field advantage was found for happy faces.

Schwartz, Ahern, and Brown (1979) used electromyography to measure facial asymmetries during spontaneous facial expressions. They found that contractions on the right side were stronger during states of happiness and excitement, and that left-sided contractions were stronger during sadness and fear. For posed expressions (in which the person is not experiencing mood), left-sided contractions were stronger regardless of the type of emotion expressed.

If the processing of positive and negative emotions is differentiated between the hemispheres, then one would expect to find an increase in right hemispheric activity during positive mood and an increase in the left during negative mood. Harmon and Ray (1977) reported an increase in left hemispheric activity in subjects experiencing positive affect, and a decrease in left hemispheric activity during negative affect states. Davidson, Schwartz, Saron, Bennett, and Goleman (1979) found an increase in left frontal activity during positive affect and an increase in right frontal activity during negative affect. Using lateral eye movements to indicate relative hemispheric activity, Ahern and Schwartz (1979) found that during states of happiness and excitement subjects tended to look right, and that during moments of fear subjects tended to look left.

A different mood is observed in patients who sustain left hemisphere damage than those with damage in the right hemisphere. Robinson, Kubos, Rao, and Price (1984) studied the mood changes of stroke patients who had no previous mood disorders. Non-aphasic patients with left anterior lesions had significantly more depression symptoms; patients with right posterior injury were also depressed, while those with right anterior lesions were inappropriately cheerful. Similarly, Sackeim, Greenberg, Weimen, Gur, Hungerbuhler, and Geschwind (1982) studied stroke patients and found that those whose lesions were in left hemisphere experienced crying and negative mood change. The patients with right lesions were inappropriately cheerful and had positive mood change. These results have been interpreted as indicating that low activation of the left hemisphere relative to the right is involved in dysphoric mood states, while the low activation of the right hemisphere is related to euphoric mood states.

Most of the studies concerning hemispheric processing of mood have involved examinations of asymmetries of the frontal regions of the brain. It appears that how the hemispheres are involved in mood may differ for anterior and posterior regions (Heller, 1986). Evidence has shown that the right parietal lobe is involved in depression. Tucker et al. (1981) induced elated and depressed moods in college students. When in the depressed mood the subjects showed impaired imagery and a right ear attentional bias on the tasks they completed.

Depressed individuals do poorly on visuospatial tasks. Kronfol, Hamsher, Digre, and Waziri (1978) compared the performance of clinically depressed individuals on cognitive tasks associated with posterior sections of the right hemisphere (judgement of line orientation, 3-dimensional praxis, and face recognition) before and after electroconvulsive therapy (ECT). Before ECT the patients' performances were poor; however, after ECT the performances, as well as the depression, were significantly improved.

As described by Tucker et al. (1981), deficits in right temporo-parietal functions have been found in clinically depressed individuals (unipolar, endogenous). Furthermore, overall arousal seems to be affected by right parietal damage. For example, hemi-neglect is more severe when the lesion is to the right parietal region than to the left (Springer & Deutsch, 1989). Such findings are consistent with the low levels of arousal exhibited by depressed individuals.

To investigate how negative mood affects functioning of posterior brain regions, Banich, Stolar, Heller, and Goldman (1989) had subjects perform a digit-matching task after undergoing a mood induction procedure. Some subjects were induced into a depressed mood, while others were inducted into a neutral mood. In the neutral group, a left visual field advantage was found for the digit-matching talk, as had been reported previously (Banich & Belger, in press). In the depressed group, however, a decrease in the left visual field advantage was detected in the subjects' reaction times.

These results support the theory that depression is related to deficient functioning of posterior regions of the right hemisphere. However, they do not preclude the possibility that all negative emotion is associated with deficient functioning of right posterior regions. One way to disentangle this possibility is to examine performance when another negative mood, such as anxiety, is induced In particular, if deficient functioning of right posterior regions is associated with low arousal, then a negative emotion associated with high levels of arousal, such as anxiety, would not be expected to create deficiency in right hemisphere performance. The current experiment examines the effect of anxious mood on performance of the digit-matching task used in Banich et al. (1989). If negative emotion in general affects right posterior functioning, then subjects in an anxious mood state will show a decrease in the right hemisphere advantage on the task, just as the depressed subjects in the Banich et al. study (1989). However, if no decrease in reaction time is found for subjects in an anxious mood, then we may conclude that a deficit in right posterior functioning is specific to depression.

Furthermore, some research suggests that interaction between the hemispheres may be deficient in certain individuals with psychopathology. To examine this possibility, we compared performance on the digit-matching task when the matching digits were directed to the same hemisphere (within-field), as compared to opposite hemispheres (across-field). The former condition does not require interhemispheric integration, whereas the latter does. Another possibility is that anxiety might decouple the processing of the two hemispheres. The digit-matching task yields a within-field advantage compared to across-field (Banich et al., 1989). If anxiety leads to a decoupling of the hemispheres, then the within-field advantage should be even greater.

Method

Subjects

Subjects were 22 students of the University of Illinois, who participated in the study either for monetary reimbursement or class credit. Of the 22, 11 were women and 11 were men. All subjects were right-handed. Handedness was assessed by a questionnaire (a variation of the Edinburgh Inventory) that determined lateral preference for items such as writing, hammering a nail, and throwing a ball (Oldfield, 1971). All subjects had normal or corrected-to-normal vision and were screened for a lateral phoria by use of a stereoscope and Maddox rod.

Mood induction procedure

Anxious and neutral moods were induced in all subjects in two different sessions. Eleven subjects received the anxious mood induction first and 11 subjects the neutral mood first; the order of induction was randomly determined. For the anxious mood induction, subjects were instructed to imagine an anxiety-provoking situation, such as giving a speech in front of a large group of people. The neutral mood induction required the subjects to imagine a non-emotional event, such as getting dressed in the morning. Subjects' moods were assessed before and after the induction by a mood checklist of 72 adjectives (i. e. friendly, angry, anxious, sad) (McNair, Lorr, & Droppleman, 1981). The rating of each adjective was scored on a continuous scale with five responses including "not at all", "a little bit", "moderately", "quite a bit", and "extremely."

Digit-matching task procedure

Subjects were seated 33 centimeters in front of a computer graphics screen. Each display was an inverted triangle array of digits with a central letter at midline, whose report was used to ensure central fixation (See Figure 1). Two digits appeared at the top of the display 1.4 degrees above fixation, each of which was equally displaced from visual midline (2.8 degrees). The bottom digit was presented 1.4 degrees below fixation but more medially than the other two (1.4 degrees). Stimulus duration was 200 msec in order to preclude lateral eye movements. The subject's task was to decide as quickly and accurately as possible if the bottom item matched either of the top two. The subjects were instructed to press a button located at body midline as fast as possible when there was a match and to refrain from pressing the button when there was not.

Half of the trials contained a match and half did not. For half of the match trials, the matching digits were presented in the same visual field, and therefore were projected initially to the same hemisphere. For half of the within-field trials, both items were positioned in the right visual field (RVF) and for the other half they were positioned in the left visual field (LVF). For the other half of the match trials, one of the matching digits was initially projected to each hemisphere (across-field trials). These trials require that information be integrated across the two visual fields if the task is to be performed successfully. For half of these trials, the bottom item was presented in the LVF and for the other half in the RVF. For mismatched trials, the bottom item was presented in the LVF for half of the trials and in the RVF for the other half.

Insert Figure 1 about here

For each subject in each mood conditon RT and accuracy measures were obtained for the four different trialtypes of stimuli (LVF match, LVF mismatch, RVF match, RVF mismatch). Each trialtype contained 55 trials.

Results

Mood induction procedure

In order to determine whether the mood induction procedure was effective, the mood rating scores for subjects before and after mood induction were examined. The subjects' responses to the mood checklist were transformed from verbal labels to a scale from zero to four, with zero indicating lack of the mood labelled by that adjective and four indicating extreme presence of that mood. It was predicted that the mood scores would shift towards a more anxious state after the anxiety mood induction, but would not differ after the neutral mood induction. As a control, depression scores were also examined to ensure that anxiety specifically was increased, but not dysphoria in general. Depression scores were not expected to change after either the neutral or the anxiety mood induction.

The depressed and anxious mood rating scores were entered into a repeated measures analysis of variance with the within-subjects factor of CONDITION (neutral mood induced, anxiety mood induced), TIME (before mood induction, after mood induction), and SCALE (depressed, anxious). A three-way interaction among CONDITION by TIME by SCALE [$F(1,20)=7.04$, $p<.025$] indicated that after the anxious mood induction the subjects did indeed become more anxious, but they did not become more depressed (cell means for the 3-way interaction can be found in Figure 2). Therefore, the anxious mood induction procedure was effective. Tests of simple effects indicated that mood scores on the anxiety scale before mood induction significantly differed after mood induction when subjects were in the anxious mood state [$F(1,20)=12.05$, $p<.005$]. The subjects' mood scores on the depression scale did not differ after induction. Tests of simple effects indicated that when the subjects were in the neutral mood state the mood scores on the anxiety scale did not change after induction. Unexpectedly, the difference for the depressed scale was significant [$F(1,20)=8.89$, $p<.005$], indicating that the subjects became less depressed after the neutral mood induction.

Insert Figure 2 about here

Reaction time data

An analysis of variance on mean RT was performed with the within subjects factor of MOOD INDUCTION ORDER (neutral-anxious, anxious-neutral), TRIALTYPE (within LVF, within

RVF across bottom-LVF across bottom-RVF), MOOD (neutral, anxious), and RESPONSE HAND (left, right). The analysis revealed a significant main effect of MOOD [$F\,(1,20)=5.365$, $p < .05$]. Mean RT was shorter when subjects were induced into an anxious mood as compared to a neutral mood (see Figure 3 for mean RT), indicating that the type of mood affected RT. A significant interaction of ORDER by MOOD was found [$F\,(1,20)=6.79$, $p < .025$]. RT was shorter in the anxious condition for subjects who had undergone the neutral condition in the first session and the anxious condition in the second session [$F\,(1,20)=12.12$, $p < .005$]. However, for subjects assigned to the anxious condition in the first session and the neutral condition in the second, no effect of mood on RT was found. These results are probably due to practice effects, since subjects tended to have shorter RT in the second session.

Insert Figure 3 about here

A main effect of TRIALTYPE [$F\,(3,60)=16.73$, $p < .0001$] was found. Planned comparisons indicated that RT on within-field trials was shorter than on between-field trials [$F\,(1,20)=5.16$, $p < .05$]. Furthermore, RT was shorter for RH (wLVF, across bottom-RVF) than LH (wRVF, across bottom-LVF) [$F\,(1,20)=38.85$, $p < .0001$]. These results are consistent with previous findings (Banich, unpublished doctoral dissertation; Banich and Belger, in press). The MOOD by TRIALTYPE interaction was not significant, indicating that the pattern of response did not differ between neutral and anxious mood states.

Digit-task accuracy

The error-rate analysis was consistent with the RT analysis. An analysis of variance on mean error rate was performed with the within subjects factor of MOOD INDUCTION ORDER (neutral-anxious, anxious-neutral), TRIALTYPE (within LVF, within RVF), MOOD (neutral, anxious), and RESPONSE HAND (left, right). A significant interaction of ORDER by MOOD was found [$F(1,20)=21.64$, $p<.0005$], indicating that subjects' accuracy increased during the anxious mood state (see Figure 2). A main effect of TRIALTYPE was found [$F(3,60)=3.22$, $p<.05$]. Newman-Keuls pairwise comparison of the cell means for the four trialtypes revealed that accuracy in across bottom-LVF was significantly lower than wRH, wLH, and across bottom-RVF (these three did not differ among themselves).

Discussion

This study supports the notion that anxiety and depression do not have the same effect on the right parietal region. In the present study the RTs became shorter after subjects were given the anxious mood induction, whereas the subjects in the Banich et al. (1989) study became slower after being induced into a depressed mood.

Furthermore, the subjects who had been induced into a depressed mood showed a specific pattern of results; reaction time were significantly longer to trials that had to be processed by the right hemisphere. Although it was predicted that anxiety might affect the right and left hemispheres differentially, this was not found. It was predicted that RT would be significantly shorter for trials that had to be processed by the RH. However, there was no significant MOOD by TRIALTYPE interaction, indicating that there was no difference in the subjects' patterns of response when they were in the neutral and anxious mood states. One explanation for these results could be that the mood induction procedure was not effective. However, based on the subjects' self-reports on the mood checklist, they did indeed become more anxious after the anxiety mood induction. In addition to the self-reports, the subjects' RT to the digit-matching task was shorter in the anxious mood state than they in the neutral mood state. The decrease in RT as a function of mood induction is consistent with our predictions.

Perhaps another explanation for these results could be that anxiety that is induced in a laboratory is not intense enough to significantly increase arousal in the right posterior region of the brain. Due to ethical reasons, our mood induction could not cause the subjects to experience high levels of anxiety. Therefore, to induce an anxious mood, the subjects were given the scenario on which they should concentrate (giving a speech for which they were unprepared) that would not be harmful to their psychological well-being.

In contrast, the subjects in the study by Banich et al. (1989) were allowed to concentrate on a personal incident that was extremely sad (such as a family member's death) to induce a depressed mood. If the subjects in the present study could have concentrated on a personal life event that is associated with anxiety, then they may have experienced a stronger anxious mood.

Another diffence between the present study and the one by Banich et al. (1989) pertains to the experimental designs. The depression study was a between-subjects design, with one group of subjects being induced into a depressed mood, and the other group being assigned to the neutral mood induction. Since the present study involved a within-subjects design, there are many factors that may affect the results. The ORDER by MOOD interaction indicates that anxiety decreased RT only for subjects who had been induced into an anxious mood in the second session. An explanation for this order effect could be that the subjects who had undergone the neutral mood induction in the first session had no expections about the second session. Therefore, their anxious mood states, along with the practice they had already received, enhanced their performance on the digit-matching task. However, the subjects who had been induced into an anxious mood state in the first session may have had negative connotations associated with the experiment when they returned for the second session. Because the anxiety may have prevented them from becoming used to the task in the first session, these subjects did not have the advantage that subjects assigned to the Neutral-Anxious order may have had.

Our results suggest that anxiety does not selectively enhance right hemisphere performance on cognitive tasks. However, because anxiety does result in an overall decrease, rather than an increase in RT to the digit-matching task, we may conclude that anxiety does not affect cognitive functioning in the same manner as depression. Therefore, it is not negative mood in general, but specifically depression that is associated with deficient functioning of right posterior regions.

While this study involved the effect of negative mood on right hemisphere performance, it would be interesting to see how positive mood affects cognitive performance. Since the left hemisphere is believed to be involved in the processing of positive emotion, a future study could examine how a positive mood state would influence cognitive tasks that require the left hemisphere, such as reading or solving a mathematical problem. PET scanning is another method that could be useful in observing how mood affects hemispheric processing. A study could focus on how subjects' PET readings differ, depending on their mood, while they perform a task. The study of emotion and how it affects the way the brain functions will continue to expand as technology is improved.

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Figure Captions

Figure 1. Examples of Match and Mismatch trials, including the four possible trialtypes

Figure 2. Subjects' mean mood scores on the anxiety and depression scales before and after neutral and anxious mood inductions.

Figure 3. Subjects' mean response times on the four matching trial types during neutral and anxious mood conditions.

Match Trials

Within LVF

2		3
	A	
2		

Within RVF

2		3
	A	
		3

Across b-LVF

2		3
	A	
3		

Across b-RVF

2		3
	A	
		2

Mismatch Trials

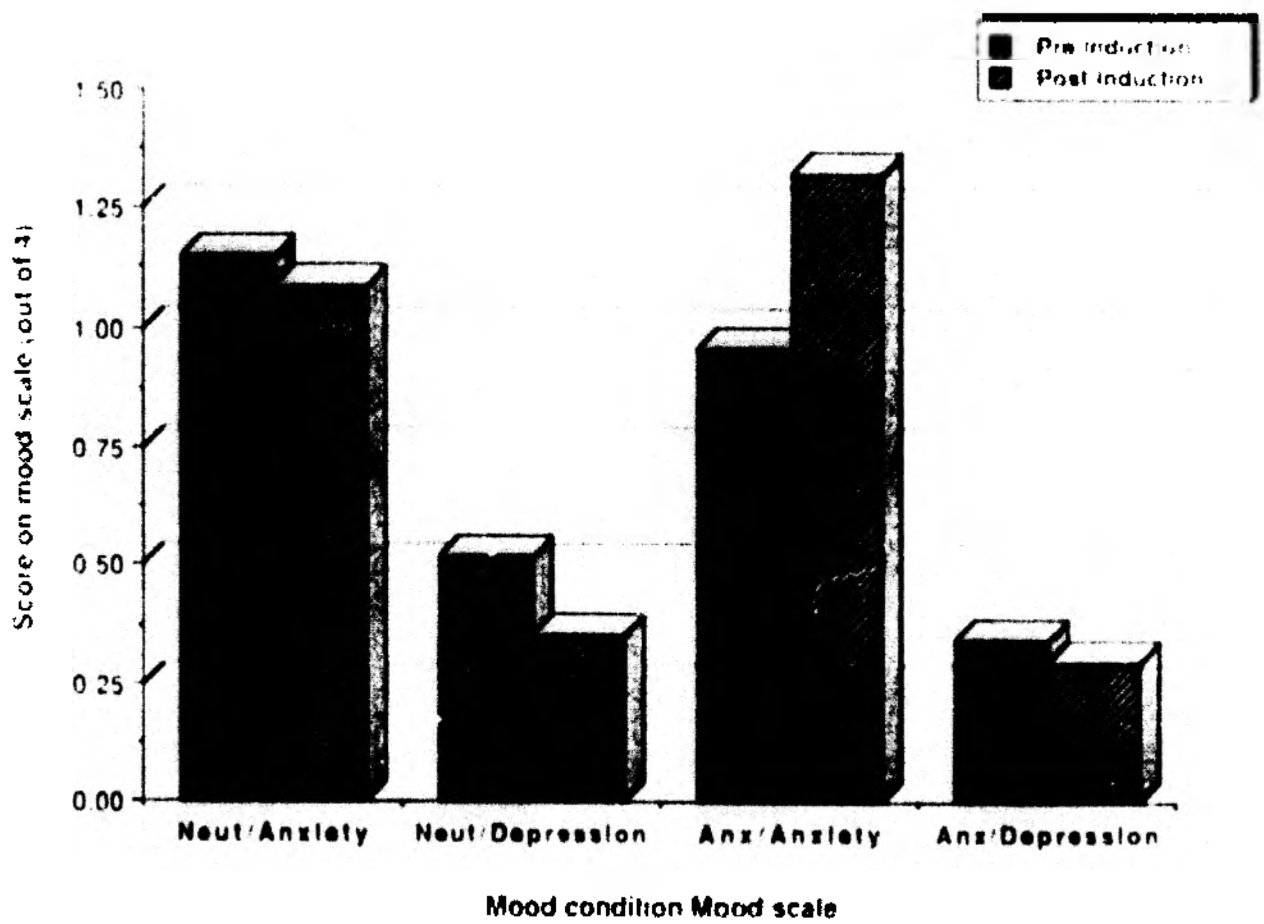
Mismatch LVF

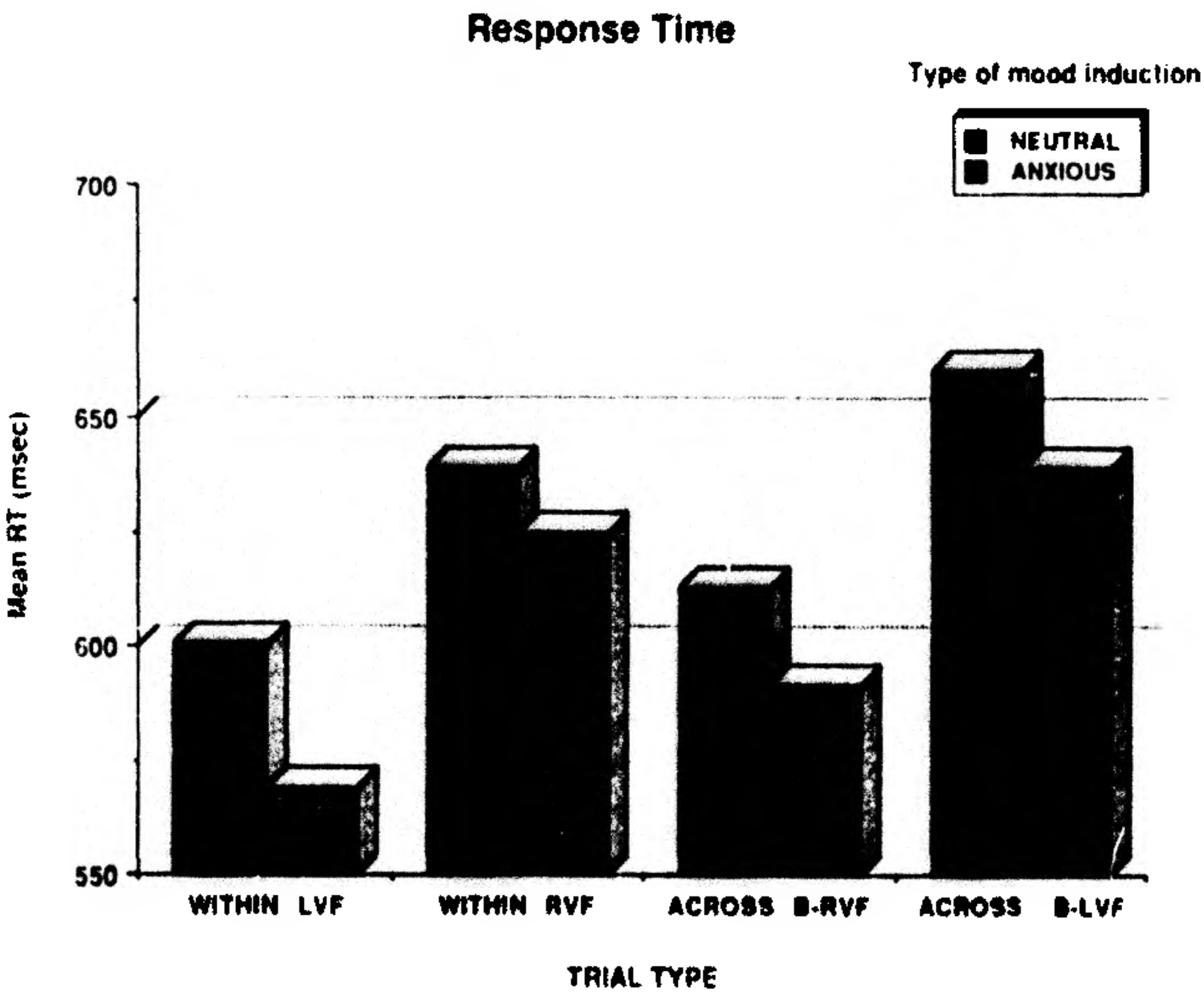
2		3
	A	
5		

Mismatch RVF

2		3
	A	
		5

Mood scores before and after mood induction




Response Time
Type of mood induction
NEUTRAL
ANXIOUS
700
650
600
550
Mean RT (msec)
WITHIN LVF
WITHIN RVF
ACROSS B-RVF
ACROSS B-LVF
TRIAL TYPE